ORIGINAL RESEARCH

Accuracy of the Light-induced Fluorescent Intraoral Camera in Occlusal Caries Detection

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Abstract

Aim and objective: This study was conducted to evaluate the accuracy of a light-induced fluorescence intraoral camera vs the visual–tactile assessment method according to the modified International caries detection and assessment system-II (ICDAS-II) criteria clinically in the detection of initial occlusal caries.

Materials and methods: Occlusal surfaces of 260 molar and premolar teeth from 52 adult participants were examined by two calibrated observers, using two diagnostic methods. Teeth were initially assessed visually according to the criteria of the ICDAS-II, and then by fluorescence camera (Soprolife®). Inter- and intraobserver agreements were measured using Cohen's kappa test. Correlation between methods was calculated using Wilcoxon signed-rank test, and effect size for comparison between the two modalities. The sensitivity, specificity, predictive values, diagnostic accuracy, likelihood ratios (LRs), area under the receiver operating characteristic (ROC) curve (AUC), and 95% confidence interval (95% CI) of the AUC for caries detection by Soprolife® were evaluated.

Results: A significant positive correlation was found between the ICDAS-II and camera measurements (p-value <0.001, effect size = 0.572). The sensitivity of Soprolife® was 94.2%, specificity 84.2%, positive predictive value 87.1%, negative predictive value 92.8%, positive LR 6%, negative LR 0.07%, and the diagnostic accuracy 89.5%. AUC was 0.909 with 95% CI (0.863–0.955). There was a perfect intraobserver agreement (kappa = 1.00) for both testing modalities. There was moderate interobserver agreement (kappa = 0.520) with regards to ICDAS, while for Soprolife®, there was substantial interobserver agreement (kappa = 0.798).

Conclusion: Soprolife® can be used as a valid and reliable assessment tool for occlusal caries detection.

Clinical significance: Light-induced fluorescence intraoral camera is an efficient tool in the detection of initial occlusal caries.

Keywords: Caries detection, Fluorescence camera, Initial caries, International caries detection and assessment system-II, Occlusal caries.

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Introduction

Dental caries is a biofilm-mediated and multifactorial disease that is mostly a result of an imbalance in the oral flora (biofilm), which is termed dysbiosis. Such imbalance results from the presence of fermentable dietary carbohydrates over the tooth surface throughout time with subsequent acid production. Dental decay is considered a crucial global health issue, affecting up to 60–90% of schoolchildren and adults. Its prevalence is around 80% worldwide; moreover, in Egypt, it is up to 60% according to a World Health Organization survey conducted in 2014. Currently, a paradigm shift from an invasive to a conservative approach in the management of dental caries is needed. On the contrary, the absence of efficacious, easy, and reliable discovery and quantification methods for initial caries will result in a profession focused only on invasive management of the cavitated lesions.[1] Furthermore, many dentists fail to determine the stage of enamel caries, which dictates the conservative rather than invasive intervention. For that reason, accurate preoperative diagnosis of initial caries is a vital point for the establishment of sufficient precautionary actions, and avoidance of premature tooth treatment by restoration.[2]

Proper action towards dental caries needs the detection of carious lesions to be done at a primary stage, which should be started with caries risk assessment. This could aid in the determination of the caries risk grade of an individual, and subsequently the prediction of future caries.[3] Lately, there are two main methods designed to help clinicians during the process of caries detection on tooth surfaces, which include a well-standardized visual–tactile examination and using light-based caries diagnostic tools. Advances in technology to detect and quantify initial carious lesions together with caries dynamics can help to identify patients needing intensive protective interventions.[2]

International caries detection and assessment system (ICDAS) based on the standard method for visual diagnosis of dental caries has been widely used as the gold standard for clinical diagnosis of dental caries.[4] The visual examination has several restrictions in practice. The most obvious limitation is its dependence on subjective visual assessments of the practitioner; thus, lesions may go unnoticed. Recent diagnostic tools, which are based on light interaction with the tooth structure, use laser or visible light

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technology. Fluorescence of bacterial byproducts or tooth structure, upon exposure to light, is used in qualitative and quantitative analyses of affected teeth. In contrast to visual examination, light-induced fluorescence systems allow for inspection of the lesion and its actual structure in a maximized view.[5]

There are currently no clinical trials in the literature that have tested the diagnostic accuracy of recent diagnostic tools used to identify caries among the Egyptian population. Therefore, this diagnostic accuracy study was designed to evaluate the clinical accuracy of light-induced fluorescence-based device (Soprolife®) vs clinical examination using the ICDAS criteria for the detection of early occlusal caries within non-cavitated discolored pits and fissures, in permanent premolars and molars among samples of the Egyptian population.

Materials and Methods

Armamentarium and materials used in the study are presented in Table 1.

Methods

Study Design and Setting

This study is a diagnostic accuracy study. The protocol of the current study was registered (www.clinicaltrials.gov NCT03586713). All procedures performed in this study, involving human participants, were by the ethical standards of the Research Ethics Committee of the Faculty of Dentistry, Cairo University (Approval no. CREC56718). This diagnostic clinical study was held in the outpatient clinic of the Department of Conservative Dentistry, Faculty of Dentistry, Cairo University, Egypt.

Sample Size Calculation

Based on a previous study conducted by Zeitouny et al., the inter-class correlation coefficient computed to assess the reliability between the two diagnostic methods was 0.92 with 0.901–0.940 confidence level. Using the power of 80% and confidence level 95%, it was found that a minimum of 166 teeth for both methods would be required. The sample size was calculated using PASS 2008 software. About 52 participants were enrolled: 24 females (46.2%) and 28 males (53.8%). The mean (standard deviation) values for age were 26.1 (6.5) years with a minimum of 19 years and a maximum of 39 years old. The numbers of teeth included in this study were 260 teeth (130 upper (50%) and 130 lower teeth (50%)). Premolars comprised 40% of the examined teeth, while molars were 60% of the examined teeth.[2]

Eligibility Criteria

Inclusion and exclusion criteria used for enrolment of participants and investigated teeth[6] are presented in Table 2.

Table 1: Armamentariums and materials names used in this study, description, lot number, and manufacture

Armamentariums or materials name	*Description*	*Lot number*	*Manufacture*
Soprolife® intraoral camera	Light-induced fluorescence intraoral camera	F0370	SOPRO, ACTEON Group, La Ciotat, France http://www.acteongroup.com/
Diagnostic mirror	Non-magnifying mirror, front-surface mouth mirror	32410 H55-4060	Hu-Friedy, USA http://www.hu-friedy.com/
Community periodontal index of treatment needs (CPITN) probe	Graduated probe with a very small ball burnisher at its tip. It has a thin handle with lightweight (5 g). The probe has a ball tip of 0.5 mm, with a black band between 3.5 and 5.5 mm, as well as black rings at 8.5 and 11.5 mm	41000000	Premium instruments, German http:/www.Premium Instruments.com/
Prophy-Mate neo	Air-powered tooth polishing system	Y135-029	NSK, Japan
Flash pearl	Small and spherically shaped particles of calcium carbonate powder	Y900693	http://www.japan.nsk-dental.com/products/oral-
MI Paste Plus®	Remineralizing agent containing 900 ppm fluoride, calcium phosphate, and milk-derived protein casein phosphopeptide (CPP)	180522	GC USA https://www.gcamerica
Embrace™ Wet Bond™	Bioactive pits and fissures sealant. It is light-cured resin filled with resin-based glass particles hydrophilic di-methacrylic esters	180926	Pulpdent Corporation, USA https://www.pulpdent.com
Scotchbond™ Universal	32 wt% phosphoric acid etchant with pH of ≈ 0.1. Its viscosity is modified with fumed silica and a water-soluble polymer	41263	3M™ ESPE™, USA www.3MESPE.com
Prime & Bond universal™	Universal adhesive with multifunctional acrylate as a surface active crosslinker, phosphoric acid modified acrylate resin, adhesion promoter primer, initiator, stabilizer, isopropanol solvent, and water	78467	Dentsply, Germany www.dentsply.eu
Filtek™ Z350 XT	Nanohybrid resin composite has bisphenol A diglycidyl methacrylate (bis-GMA), urethane dimethacrylate (UDMA), triethylene glycol dimethacrylate (TEGDMA), bisphenol A diglycidyl methacrylate (bis-EMA) resins. To control the shrinkage, polyethylene glycol dimethacrylate (PEGDMA) was replaced using a portion of the TEGDMA resin in Filtek™ Supreme XT restorative. The fillers are a mixture of non-agglomerated/non-aggregated 20 nm silica filler, non-agglomerated/non-aggregated 4–11 nm zirconia filler, and aggregated zirconia/silica cluster filler (made up of 20 nm silica and 4–11 nm zirconia particles)	7018a3b	3M™ ESPE™, USA www.3MESPE.com

Table 2: Inclusion and exclusion criteria of participants and teeth

Inclusion criteria	*Exclusion criteria*
Patients aged from 15 to 40 years with no gender restriction	Patients with a compromised medical history as they may take any medicine or treatment that can affect oral hygiene
Patients should have an acceptable oral hygiene level (mild and moderate risks)	Severe or active periodontal disease as it may reflect bad oral hygiene
Patients must have at least one posterior molar or premolar with discolored fissure	Heavy bruxism or traumatic occlusion as the fissure may be disappeared
Intact occlusal enamel surface	Teeth with any kind of malformations, such as fluorosis, enamel hypoplasia, amelogenesis imperfecta, hypo-mineralization, and/or frank occlusal cavitation
Free from heavy calculus deposits	Teeth with intrinsic or extrinsic staining (possibility of false positive results)
Teeth with ICDAS codes from 0 to 2	Teeth with coronal sealants/restorations (out of this study scope)
	Teeth having large carious lesions on smooth and proximal surfaces (they affect the occlusal reading)
	Third molars were not included (inability to standardize the position of Soprolife® head over the tooth)

Enrolment and Variables of this Study

A non-probability convenient sampling method was employed to carry out this study. A total of 52 participants were included in this study after describing the research procedure in-depth and obtaining informed consent. Each had at least one non-cavitated occlusal carious lesion in each quadrant (maxilla and mandible) in the first and/or second molar and premolar, resulting in a total of 260 examined teeth. Each lesion had been evaluated by two diagnostic methods: visual assessment method (ICDAS-II criteria) and light-induced fluorescence camera.

Clinical Examination

The examiners were not blinded; however, it was not allowed among the examiners to exchange any information throughout the entire study period. The diagnosis by ICDAS-II was done before the Soprolife® method to avoid bias by knowing the results from the second method. Additionally, when the same examiner was re-diagnosing the same case, the case report of the participant was hidden. Examiner 1 (co-supervisor) had previous experience using ICDAS-II criteria and the fluorescence-based caries detection camera. Calibration sessions were arranged for the two examiners regarding the two methods 20 days before the research was started. They were trained clinically by examining 100 premolars and molars teeth. Each examiner diagnosed the teeth and recorded the results. Then, they compared the observations and checked the calibration inconsistencies till they reached a full consistency. Finally, inter- and intraobserver agreements were measured using Cohen's kappa coefficient.

The examinations for both the visual and fluorescent methods, with both examiners, were performed at the surface level of the teeth. The surfaces chosen for scoring were identical for both methods. The illumination, cleaning, and drying procedures were the same in the diagnoses of all patients.[7]

Before the visual examinations, scaling of all the teeth was done carefully to eliminate the surface biofilm and deposits.[8] The occlusal surface of every tooth was cleansed for 10 seconds, using a water powder jet cleaner and calcium carbonate powder (Electro Medical System, EMS) (Prophy-mate, NSK, Japan). Cleansing was followed by rinsing using an air–water spray for an extra 10 seconds duration to eradicate all powder leftovers from the fissure. After preparing the tooth surfaces, all examinations took place in standardized conditions, including a professional dental light with a front-surface dental mirror, a lightening system, and an oil-free air syringe used for 5 seconds for dryness. The drying process is a prerequisite for both the ICDAS-II and Soprolife® assessment.[2]

Visual Examination

Examiners evaluated the teeth under wet conditions, then under dry conditions, by drying the teeth for 5 seconds using a triplex syringe and then rewet again.[9] The points being evaluated were the changes in translucency and color, which denote the state of demineralization of surface and subsurface zones in comparison with nearby healthy areas.[3] The uppermost ICDAS score on every occlusal surface was recorded at the investigation spot. The exact location was stated in the patient's files; distal, central, or mesial part of each occlusal surface as depicted in sheets. These visible signs indicating caries have been rationalized and classified using the classification system (ICDAS-II) that includes six codes (Table 3 and Fig. 1).

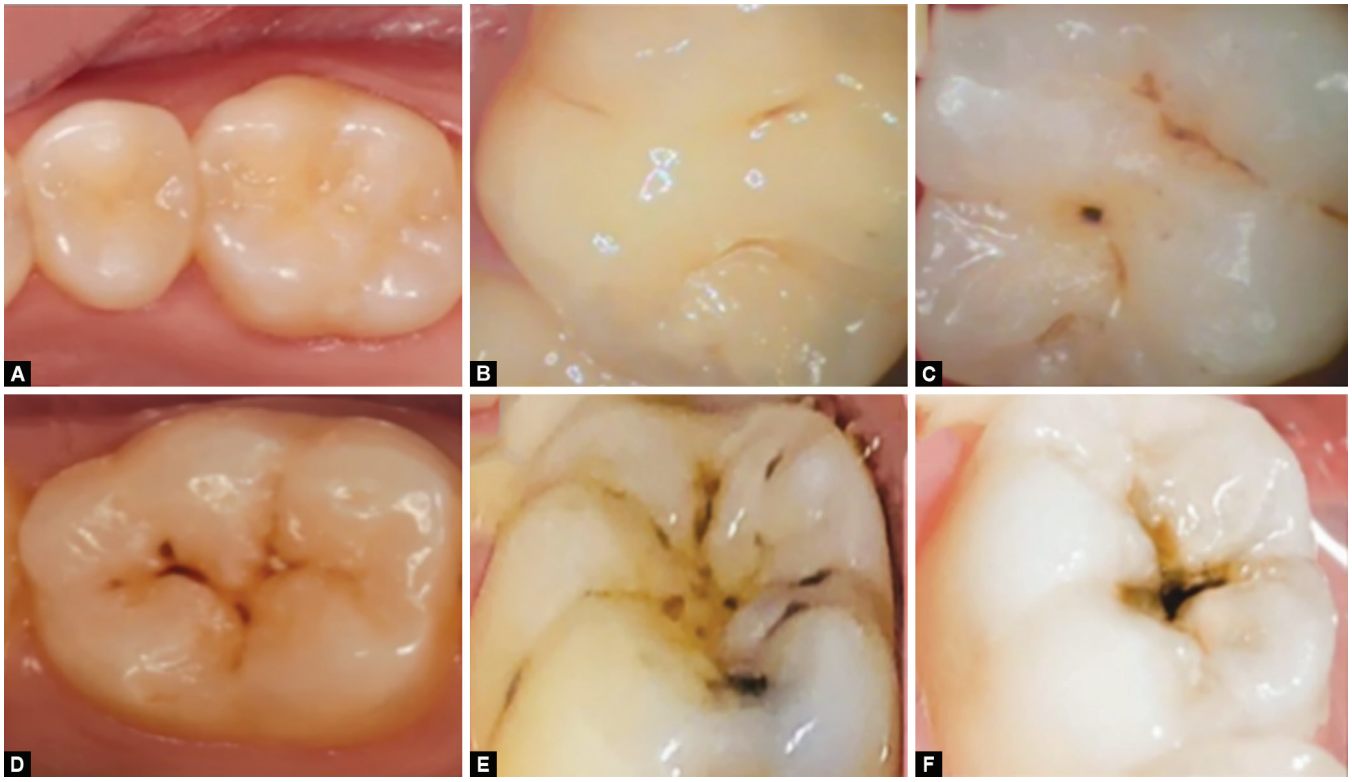
Light-induced Fluorescence Intraoral Camera

After visual examination, fluorescence calculations were performed on the teeth using the fluorescence camera (Soprolife®) according to the manufacturer's instructions. Before use, the head of the intraoral camera was placed inside a special hygienic protective wrap provided by the manufacturer, and the camera was connected to a computer. Proper isolation with cotton roll, suction tip, and tooth drying with a triplex air syringe for 15 seconds was done.[10] The camera head was positioned perpendicularly over the occlusal surface of the teeth, with a spacer connected onto the head (Soprotips) to standardize the distance and for easier application. By pressing the control ring of the device, an image was captured which was then analyzed by the special software. The images were recorded with the Sopro Imaging software. Evaluation and grading of the occlusal fissure areas were done using the Soprolife® blue fluorescence mode. Full description of the different scores is presented in Table 4 and Figure 2, with grading system according to Zeitouny et al.[2]

Participants who were diagnosed by ICDAS-II as score 1 or 2, the application of MI Paste Plus® took place topically over all doubtful surfaces. Firstly, cleansing of the teeth was done, followed by spreading a little quantity of MI Paste Plus® over the tooth

Table 3: ICDAS-II six codes

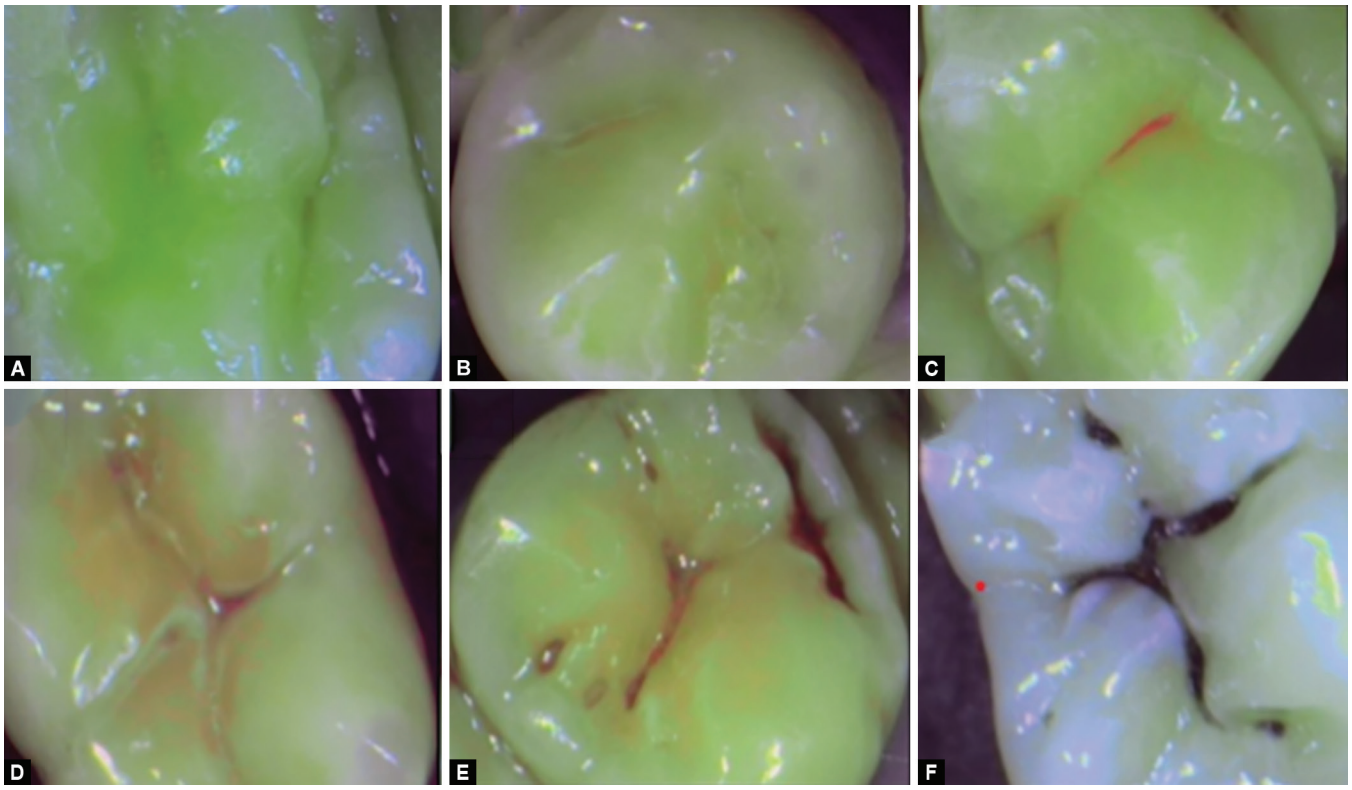
Score	*Description*
Code 0	Sound tooth surface. No alterations in enamel translucency are evident following a period of 5 seconds of air dryness
Code 1	Initial visual alteration in enamel. During wetness, no proof of any alteration in color, yet after 5 seconds of air dryness, a carious opacity/discoloration is evident that is unrelated to the clinical picture of sound enamel and is restricted to the boundaries of the pit and fissure areas
Code 2	Distinct visual alteration in enamel. During wetness, a carious opacity and/or brown carious discoloration with a greater width when compared with a fissure (the lesion remains noticeable on dryness)
Code 3	Localized enamel collapses due to caries without observable dentin or underlying shadow. During wetness, a carious opacity and/or brown carious discoloration with a greater width when compared with a fissure. On dryness, for around 5 seconds, carious loss of tooth structure by the entrance to, or inside, the pit or fissure/fossa, but in the walls or base of the discontinuity, dentin is not observed
Code 4	Dark underlying dentin shadow with or without enamel breakdown. This lesion is described as a shadow visible from an intact enamel surface of discolored dentin that may or may not display signs of localized breakdown. The darkened area can have a color of gray, blue, or brown and is detected during wetness with greater ease
Code 5	Distinct dentin-visible cavity. Cavitation in the opaque or discolored enamel underneath which exposes the dentin



Figs 1A to F: Photographic images for the ICDAS-II codes: (A) Code 0; (B) Code 1; (C) Code 2; (D) Code 3; (E) Code 4; (F) Code 5

Table 4: Soprolife® blue fluorescence mode score with Soprolife® intraoral camera

Score	*Description*
Code 0	Fissure shows a shiny green color, the enamel has a sound appearance, without observable changes
Code 1	Tiny, thin red shimmer in the pits and fissures system is noticed, that could somewhat complete its course upwards along the slopes (walls) of the fissure system. No evidence of red dots
Code 2	Darker red spots limited to the fissure are noticeable
Code 3	Extension of dark red spots as lines into the fissure areas, yet still restricted to the fissures. Some roughness is evident of the more lined red areas
Code 4	Dark red (or red-orange) extends with a greater width than the boundaries of the fissures
Code 5	Obvious openings of enamel were seen with visible dentin



Figs 2A to F: Photographic images for the light-induced fluorescence intraoral camera mode score: (A) Code 0; (B) Code 1; (C) Code 2; (D) Code 3; (E) Code 4; (F) Code 5

surfaces using a spotless cotton-tipped applicator. The paste was left undisturbed for a minimum of 3 minutes, according to the manufacturer's instructions.

Others who were diagnosed by ICDAS-II as score 3, pits and fissures sealant with Embrace™ Wet Bond™ was applied. Furthermore, cavitated teeth with a score of more than 3 were restored by a suitable shade matching nanohybrid resin composite.

Statistical Analysis

The presentation of qualitative data (scores) was done as frequencies and percentages. Comparisons between the two groups took place using Wilcoxon signed-rank test. The significance level was set at $p \leq 0.05$. Statistical analysis was accomplished with IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp. A receiver operating characteristic (ROC) curve was created to determine the diagnostic accuracy measures of Soprolife® using ICDAS as the reference standard. ROC curve analysis was done via MedCalc Statistical Software Version 16.4.3 (MedCalc Software Bvba, Ostend, Belgium; https://www.medcalc.org; 2016).

Results

Inter- and Intraobserver Agreement

As regards ICDAS, there was moderate interobserver agreement (kappa = 0.520), whereas for Soprolife® there was substantial interobserver agreement (kappa = 0.798). For both ICDAS and Soprolife®, there was a perfect intraobserver agreement (kappa = 1.000). Table 5 shows comparisons between the two diagnostic modalities regarding the different scores.

Table 5: Results of kappa statistic for inter- and intraobserver agreements regarding the two modalities

		Intraobserver	
Modality	*Interobserver*	*Observer 1*	*Observer 2*
ICDAS	0.520	1.00	1.00
Soprolife®	0.798	1.00	1.00

Table 6: Descriptive statistics, results of Wilcoxon signed-rank test, and effect size for comparison between the two modalities

	ICDAS (n = 260)	*Soprolife® (n = 260)*		
Scores	*n (%)*	*n (%)*	*p-Value*	*Effect size (r)*
Score 0	88 (33.8)	80 (30.8)		
Score 1	119 (45.8)	45 (17.3)		
Score 2	42 (16.2)	91 (35)	<0.001*	0.572
Score 3	10 (3.8)	38 (14.6)		
Score 4	1 (0.4)	6 (2.3)		

*p-value is significant at $p \leq 0.05$

The results of Wilcoxon signed-rank test and effect size for comparison between the two modalities are presented in Table 6. There was a statistically significant difference between scores of the two modalities (p-value < 0.001, effect size = 0.572). Soprolife® showed a lower prevalence of scores 0 and 1 than ICDAS (ICDAS score 0 was 33.8% and score 1 for ICDAS was 45.8%, whereas

Soprolife® score 0 was 30.8% and for score 1 Soprolife® was 17.3%). ICDAS showed a lower prevalence of scores 2, 3, and 4 (for ICDAS score 2 was 16.2% and for Soprolife® was 35%, while score 3 was for ICDAS 3.8% in Soprolife® was 14.6%, and for score 4 it was for ICDAS 0.4% and for Soprolife® was 2.3%), than Soprolife®.

Diagnostic Accuracy of Soprolife®

The reference standard was ICDAS scores 0 and 1, which represented sound and subclinical lesion, whereas all other scores are considered clinically carious lesions.

Overall Accuracy

The sensitivity, specificity, predictive values, diagnostic accuracy, likelihood ratios (LRs), area under the ROC curve (AUC), and 95% confidence interval (95% CI) of the AUC for caries detection by Soprolife® are presented in Table 7. ROC curve analysis revealed that sensitivity of Soprolife® was 94.2%, specificity 84.2%, positive predictive value 87.1%, negative predictive value 92.8%, positive LR 6%, negative LR 0.07%, and the diagnostic accuracy was 89.5%. AUC was 0.909 with 95% CI (0.863–0.955).

Diagnostic Accuracy of Caries Detection in Upper and Lower Teeth

The sensitivity, specificity, predictive values, diagnostic accuracy, LRs, AUC, and 95% CI of the AUC for caries detection by Soprolife® in upper and lower teeth are presented in Table 7. ROC curve analysis revealed that the sensitivity of Soprolife® was higher in the upper arch than the lower arch (100% and 88.4%, respectively). Specificity was higher in the lower arch than the upper arch (91.4% and 78.1%, respectively). Diagnostic accuracy was nearly similar in upper and lower arches (89.3% and 89.7%, respectively). The AUC was higher in the upper arch than the lower arch (0.925 and 0.905, respectively).

Accuracy of Caries Detection in Premolar and Molar Teeth

The sensitivity, specificity, predictive values, LRs, diagnostic accuracy, AUC, and 95% CI of the AUC for caries detection by Soprolife® in premolar and molar teeth are presented in Table 7.

ROC curve analysis revealed that the sensitivity of Soprolife® was higher in molar than premolar teeth (97.5% and 91.3%, respectively). Specificity was higher in premolar than molar teeth (87.9% and 81.4%, respectively). Diagnostic accuracy was nearly the same in premolars and molars (89.9% and 89.2%, respectively). The AUC was higher in premolar than molar teeth (0.933 and 0.907, respectively).

Discussion

Epidemiological studies in contemporary populations have shown that molars and premolars are considered the most susceptible teeth for caries outbreak, due to the morphological structure of their occlusal surfaces, and the uneasiness in plaque elimination.[2,11] For these reasons, the current study was carried out to evaluate the diagnostic accuracy of a light-induced fluorescence intraoral camera in comparison with the visual–tactile assessment technique using the ICDAS-II scoring system in the detection of initial occlusal caries in molars and premolars.

Central to the vision of awareness of preventive therapies is the ability to spot caries lesions at a primary stage, and to measure the extent of mineral loss, guaranteeing a suitable interference.[12] On the contrary, deficiency in the diagnostic tools regarding early identification of carious lesions will lead to a profession only practicing overtreatment of initial carious lesions.[1]

A moderate interobserver agreement was found regarding the visual inspection by ICDAS-II, whereas for Soprolife® there was substantial interobserver agreement. These results may be due to the calibration sessions which were arranged for the two examiners regarding the optimal use of the two diagnostic methods.[2] On the contrary, the intraobserver agreement for both ICDAS and Soprolife® between both observers showed perfect intraobserver agreement. This shows that the diagnosis performed using visual examination was approximately, such as the diagnosis made by Soprolife®. The interobserver agreement results agreed with Ismail et al.,[13] Diniz et al.,[14] and Bhumireddy et al.,[15] whereas Rodrigues et al.[16] found that the inter-examiner values for the ICDAS-II scoring system were slightly lower than the present findings. The inferior results in this study could be explained by different clinical experiences between examiners and short calibration periods before this study. The intraobserver reproducibility showed agreement with various studies, including Ismail et al.[13], Diniz et al.[14], and Bhumireddy et al.[15]

Almost all the studies showed adequate inter-examiner reproducibility for the ICDAS scoring system, with a varying range of agreement. The variations among different studies can be clarified using subjective features related to visual examination, such as clinical experience and knowledge of the examiners and vision precision of each examiner.[17] Besides the differences in methodology and preparations before this study, it is important to keep in mind that some investigations took place *in vivo*, whereas others were *in vitro*, which suggests the presence of dislike values of reproducibility among the studies. Also, the sample size in each study may have affected the results. The clinical significance of these findings suggested that using the camera in a long-term monitor of the carious process could take place with a high level of reproducibility.[2,5]

A strong correlation between the measurements of both ICDAS-II and fluorescence camera (0.572 positive correlation value, $p < 0.001$) was observed in this study. This suggests that as the

Table 7: Overall accuracy for caries detection by Soprolife®, upper, lower teeth, and molar and premolar teeth

	Sensitivity (%)	*Specificity (%)*	*+PV (%)*	*−PV (%)*	*+LR*	*−LR*	*Diagnostic accuracy (%)*	*AUC*	*95% CI*
Overall accuracy	94.2	84.2	87.1	92.8	6	0.07	89.5	0.91	0863–0.955
Upper teeth	100	78.1	82.7	100	4.56	0	89.3	0.93	0866–0.984
Lower teeth	88.4	91.4	92.7	86.5	10.3	0.13	89.7	0.91	0.838–0.973
Premolar teeth	91.3	87.9	91.3	87.9	7.53	0.1	89.9	0.93	0878–0.988
Molar teeth	97.5	81.4	83	97.2	5.24	0.03	89.2	0.91	0.839–0.974

p-value is significant at $p \leq 0.05$; +PV, positive predictive value; −PV, negative predictive value; +LR, positive likelihood ratio; −LR, negative likelihood ratio

reading of ICDAS-II increases, the camera measurement increases, and vice versa. However, ICDAS showed a lower prevalence of scores 2, 3, and 4 than Soprolife® (for ICDAS score 2 was 16.2% and for Soprolife® was 35%, whereas score 3 was 3.8% for ICDAS and 38% for Soprolife®, and for score 4, it was 0.4% for ICDAS and 14.6% for Soprolife®. Soprolife® showed a lower prevalence of scores 0 and 1 than ICDAS (ICDAS score 0 was 33.8%, Soprolife® score 0 was 30.8%, whereas score 1 for ICDAS was 45.8% and for Soprolife® was 17.3%). This could be explained by Lussi et al.[18] who stated that white spot lesions did not result in a significant rise in fluorescence when compared with sound surfaces clinically. Distinct fluorescence of the caries process within more advanced phases postulated that, alongside light scattering, bacteria or their metabolites can be the reason behind the fluorescence of these lesions. The carious structure had a strong fluorescence with its extreme within the red spectral area, having mostly porphyrin (byproducts). Consequently, molecules that contribute to the signs attained from caries were recognized. Mendes et al.[19] showed that the laser fluorescence device reproduces organic changes within carious lesions instead of mineral loss. During the advancement of the carious process, there is an upsurge in the quantity of fluorescent light. These results agreed with Gomez et al.[1] and disagreed with Zeitouny et al.[2] who found a nearly flawless agreement among both techniques for caries detection. This indicated that the diagnosis performed using visual examination was approximate as exact as the one performed using Soprolife®. The contradiction with this study might be related to the small sample size (21 patients). The same results were obtained by Rechmann et al.[20] and Theocharopoulou et al.[3]; however, these studies were conducted on primary teeth.

The current study showed that the fluorescence camera had a moderate level of agreement with the ICDAS-II using different measurements, including sensitivity, specificity, positive predictive value, negative predictive value, LR, the area under the curve, and the overall accuracy. The camera showed a high sensitivity value (94.2%), which indicates a strong capability in the detection of caries lesions in case of their presence. The specificity was lower (84.2%). This high sensitivity (94.2%) and specificity (84.2%) for the Soprolife® camera reflected the ability of the camera to be a reproducible and reliable device. This outstanding performance of the camera is due to a blend of visual examination (high specificity), a high-magnification oral camera, and a laser fluorescence device (high duplicability and discrimination) in the Soprolife® system.[21] Similar findings were described by Gomez et al.,[1] Zeitouny et al.,[2] and Ünal et al.[5] A study conducted by Rechmann et al.[20] evaluated the diagnostic abilities of a laser fluorescence device DIAGNOdent, two light-emitting diode fluorescence devices Spectra Caries Detection Aid, and Soprolife® light-induced fluorescence evaluator in daylight and blue fluorescence mode. The characteristics of Soprolife® were of high sensitivity for the enamel threshold, such as the ICDAS-II scoring system (95%), but the specificity dropped to 55% and this was due to the sample size being doubled (433 posterior permanent unrestored teeth were examined, whereas the sample size used in this study were 260 teeth).

A positive predictive value of 87.1% and a negative predictive value of 92.8% were recorded in this diagnostic study. These results are considered mostly reliant on disease occurrence within the examined people, positive LR (6%), and negative LR (0.07%). LRs are an extremely valuable measure of diagnostic accuracy that describes how many times more likely the test result is in subjects with the disease than in those without the disease. The diagnostic accuracy of the camera was 89.5% and the AUC was 0.909 with a 95% CI (0.863–0.955). These findings agreed with Ünal et al.[5] (AUC = 0.94) and Gomez et al.[1] (AUC = 0.98). The higher the AUC value, the higher the total ability to differentiate between "carious" and "non-carious". On the contrary, Rechmann et al.[20] revealed an AUC of 0.8854 for the Soprolife® blue fluorescence tool and Doméjean et al.[21] found AUC = 0.87.

Another finding was the higher sensitivity of Soprolife® in the upper arch than in the lower arch (100% and 88.4%, respectively). Although, specificity was higher in the lower arch than the upper arch (91.4% and 78.1%, respectively). Diagnostic accuracy was nearly similar in both arches (89.3% and 89.7%, respectively). The AUC was slightly higher in the upper arch than in the lower arch (0.925 and 0.905, respectively). This could be explained by the efficiency of dryness in the upper arch, in comparison with the lower one. Concerning laser fluorescence, dryness could alter the structure of the lesion, resulting in increased fluorescence path, altering the overall fluorescence values. During the air-drying process of sound or carious enamel, light scattering takes place within air rather than water. An increased scattering and lesser fluorescence values are present in dry enamel, in comparison with wet enamel, because of the lesser quantity of light that strikes the fluorescing centers and the screening of the fluorescence from dentin or enamel boundary.[22]

Furthermore, the sensitivity of Soprolife® was higher in molar than premolar teeth (97.5% and 91.3%, respectively). Specificity was higher in premolar than in molar teeth (87.9% and 81.4%, respectively). Diagnostic accuracy was nearly the same in premolars and molars (89.9% and 89.2%, respectively). The AUC was higher in premolar than molar teeth (0.933 and 0.907, respectively). This could be explained by the ease of application of the camera, and greater accessibility of the camera in the participant's mouth in premolar more than in the molar area.

Due to the lack of strong evidence on the Soprolife® camera, more clinical trials are still required to confirm the present caries detection findings. The challenging points were the influence of the degree of tooth dryness and biofilm deposits on the tooth to be assessed on the diagnostic accuracy of the Soprolife® camera. Also, quantification of the obtained fluorescence will be a great improvement in the camera software, as the software output is only related to qualification data and so it is difficult for the examiner to analyze the qualification data accurately and detect clear cut-off points.

Finally, the overall diagnostic accuracy results of the Soprolife® camera enable it to be used in early detection, monitoring of caries lesions, and confirmation of successful preventive measures. It could also be used as an adjunctive confirmatory method with the visual inspection method to eliminate its subjective problem.

Conclusion

Despite ICDAS being financially feasible, Soprolife® can be considered as a valid and reliable diagnostic tool that is being familiar to the clinicians together with having a short learning curve.

Clinical Significance

Light-induced fluorescence intraoral camera (Soprolife®) is an efficient tool in the detection of initial occlusal caries.

Acknowledgments

All actions completed within this study, involving human participants, were according to the ethical standards of the Research

Ethics Committee of the Faculty of Dentistry, Cairo University (Approval no. CREC56718).

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